A REVISION OF THE FORAMINIFERAL GENUS *AUSTROTRILLINA* PARR

BY

C. G. ADAMS

British Museum (Natural History)

Pp. 71–97; 6 *Plates;* 3 *Text-figures*

BULLETIN OF
THE BRITISH MUSEUM (NATURAL HISTORY)
GEOLOGY Vol. 16 No. 2

LONDON: 1968

THE BULLETIN OF THE BRITISH MUSEUM (NATURAL HISTORY), *instituted in* 1949, *is issued in five series corresponding to the Departments of the Museum, and an Historical series.*

Parts will appear at irregular intervals as they become ready. Volumes will contain about three or four hundred pages, and will not necessarily be completed within one calendar year.

In 1965 *a separate supplementary series of longer papers was instituted, numbered serially for each Department.*

This paper is Vol. 16, *No.* 2 *of the Geological (Palaeontological) series. The abbreviated titles of periodicals cited follow those of the World List of Scientific Periodicals.*

World List abbreviation
Bull. Br. Mus. nat. Hist. (Geol.).

TRUSTEES OF
THE BRITISH MUSEUM (NATURAL HISTORY)

Issued 6 *February,* 1968 *Price* £1 12*s.*

A REVISION OF THE FORAMINIFERAL GENUS *AUSTROTRILLINA* PARR

By C. G. ADAMS

MS accepted May 12th 1967

ABSTRACT

The known species of *Austrotrillina* are redescribed and compared, and their geographical and stratigraphical distributions are discussed. It is concluded that the evolutionary changes observed in the wall structure are of value in stratigraphy. One new species, *A. asmariensis*, is erected.

CONTENTS

I. INTRODUCTION

Austrotrillina has long been recognized as an important mid-Tertiary index fossil in the Tethyan and Indo-Pacific regions. It is unknown from the Americas. Unfortunately, the four species so far described, *A. howchini* (Schlumberger), *A. paucialveolata* Grimsdale, *A. brunni* Marie, and *A. striata* Todd & Post, have never been adequately compared, their diagnostic characters have hitherto been uncertain and the stratigraphical value of the individual species has therefore been obscured. The purpose of this paper is to redescribe these species, to establish the facts about their geographical and stratigraphical distributions as accurately as possible, and to indicate the probable evolutionary history of the genus.

Since *Austrotrillina* occurs in both the Tethyan and Indo-Pacific provinces, it is necessary to refer here to two schemes of classification for the Tertiary (Text-fig. 1). Justification for the correlation between part of the East Indian letter stages (Tc–Te) and the European stages may be found in a recent paper (Adams 1965). It is thought wise to retain the two systems until a generally acceptable correlation becomes possible.

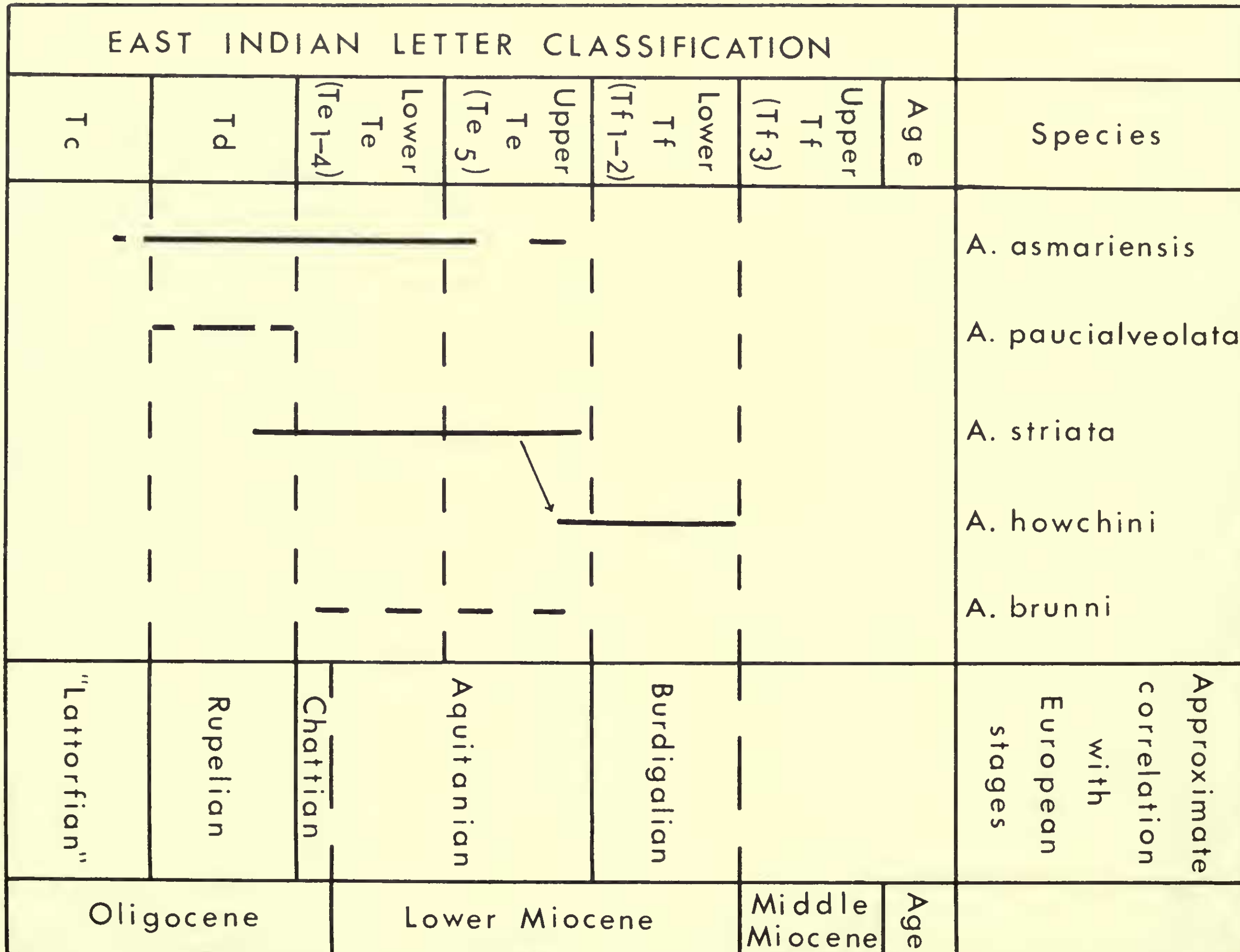


FIG. 1. *Austrotrillina* range chart. Solid lines indicate known ranges; broken lines indicate uncertainty. The European stages are used in the sense of most workers on larger foraminifera up to 1962, i.e. they are based on faunal assemblages rather than on type sections. At the top of its range, i.e. within Lower Tf, *Austrotrillina* overlaps with *Orbulina*.

It was first realized that taxonomic confusion surrounded the species of *Austrotrillina* during a study of the Tertiary faunas of Borneo. At the same time it became clear that the genus showed definite evolutionary changes during the Miocene and that if these could be shown to hold good over the whole of its distributional area, a useful stratigraphical tool would have emerged.

Although well-placed to attempt this study, the writer would have achieved little without the willing co-operation of numerous fellow workers. His special thanks are due to the following: Dr. F. E. Eames (British Petroleum Co. Ltd.) for stimulating discussions, for help in obtaining material from Iran and Malta and for critically reading the manuscript; Dr. T. D. Adams and Mr. J. D. Baignton (Iranian Oil Operating Co.) for additional material from Iran and for much useful stratigraphical data; Dr. R. C. van Bellen and Mr. G. F. Elliott (Iraq Petroleum Co. Ltd.) for the loan of material and for valuable stratigraphical evidence; Dr. N. H. Ludbrook (Department of Mines, Adelaide) for the gift of specimens from the Pata limestone, South Australia, and for much helpful information; Dr. R. Cifelli (U.S. National Museum), Miss Ruth Todd and Dr. N. K. Sachs (U.S. Geological Survey) for making available material in their care. He is also greatly indebted to Dr. F. T. Banner (British Petroleum Company Ltd.), Dr. D. J. Belford (Bureau of Mineral Resources, Canberra), Dr. A. N. Carter (University of New South Wales), Mr. D. J. Carter (Imperial College, London), Professor W. Storrs Cole (Cornell University), Professor M. F. Glaessner (University of Adelaide), Dr. L. Hottinger (University of Basle) and Dr. P. Marie (Paris) for additional information, material, or helpful discussions, Mr. R. L. Hodgkinson provided invaluable technical assistance.

II. STRATIGRAPHICAL NOTES

The species described here were obtained mainly from the successions detailed below. This stratigraphical information is given so that the conclusions regarding stratigraphical ranges and evolutionary history can be evaluated independently by other workers.

1. *The Asmari limestone*

General succession	*Age* (according to Eames *et al.* 1962)
Upper Asmari limestone	Burdigalian
Middle Asmari limestone	Aquitanian
Lower Asmari limestone	Oligocene { upper part Chattian lower part Rupelian

The Asmari limestone overlies the *Brissopsis* beds (Lower Oligocene) in some places; in others it rests disconformably on the Upper Eocene.

Whether or not the middle Asmari limestone is Aquitanian in age seems to be a matter of opinion. Direct correlation with the type Aquitanian is impossible at present, and the published evidence does not appear to disprove an Upper Oligocene age for this part of the sequence.

Material examined in this study consists of:

(a) 2,500 thin sections from wells 6 and 11, Gach Saran Oilfield, Iran. Both wells penetrated all three divisions of the limestone.

(b) The Asmari limestone at Kuh e Pataq, N.W. Luristan (46° 00′ E., 34° 25′ N.). Four samples were available from this locality, here designated as the type section for *A. asmariensis* sp. nov. The microfauna of the whole section has been studied by Dr. T. D. Adams and the ranges of important genera shown on Text-fig. 2 are based on his work. Kuh e Pataq is a surface section on the road from Kermanshah to Baghdad, near the border with Iraq (Text-fig. 2). The lowermost part of this sequence is definitely Eocene, and although it is tempting to regard the oldest Oligocene horizons as Lower Oligocene (occurrence of *Nummulites fichteli* without *Eulepidina*) caution is necessary. *Eulepidina* does not appear until 380 ft. below the top of the limestone and the overlap with *N. fichteli* is small (about 80 ft.). Reticulate nummulites occur through approximately 700 ft. of limestone and overlap with *Chapmanina* (a well-known Eocene genus) throughout their lowermost 130 ft. The writer has not seen these particular specimens and is therefore unable to confirm Dr. T. D. Adams's identification of *N. fichteli* (*in lit.*). It seems reasonable to draw the Eocene/Oligocene boundary at about 845 ft. below the top of the limestone, i.e. at the first appearance of *Austrotrillina*. It may be noted that *Austrotrillina* is not common until after the incoming of *Peneroplis thomasi* about 800 ft. from the top. By 730 ft. *P. thomasi* has already been joined by *P. evolutus* and *Praerhapydionina delicata*. The evidence of this section seems to suggest that *Austrotrillina* occurs in the Lower Oligocene. However, it can equally well be argued that this is a Middle Oligocene fauna from which *Eulepidina* is absent for facies reasons. Pending further investigation of the section—in particular, the detailed examination of the faunas immediately above the Eocene/Oligocene boundary—it would be unjustifiable to state unequivocally that *Austrotrillina* occurs in the Lower Oligocene of Kuh e Pataq, although it certainly occurs in the Middle Oligocene.

(c) The Kuh e Kalagh section (Text-fig. 2). The lowest exposed Oligocene beds in this locality are presumably of Middle Oligocene age (association of *Lepidocyclina*, in part *Eulepidina*, with *Nummulites fichteli*). The base of the Oligocene is obscured and the next visible beds are those of the Eocene Dezak Marl Member. The middle part of the section is either Chattian or Aquitanian but seems to lack diagnostic fossils; the highest levels (above sample JHT 1863 and not shown in Text-fig. 2) can reasonably be assigned to the late Lower Miocene (" Burdigalian ") on the evidence of *Borelis melo curdica*. Ninety-two samples (135 thin sections), collected through 1,138 ft. of rock, have been examined.

2. *The Main Limestone of Kirkuk.*

This limestone is well-known through the work of van Bellen (1956). It has been described from numerous wells which are difficult to correlate owing to the rapidity with which it is said to changes facies both laterally and vertically. The succession

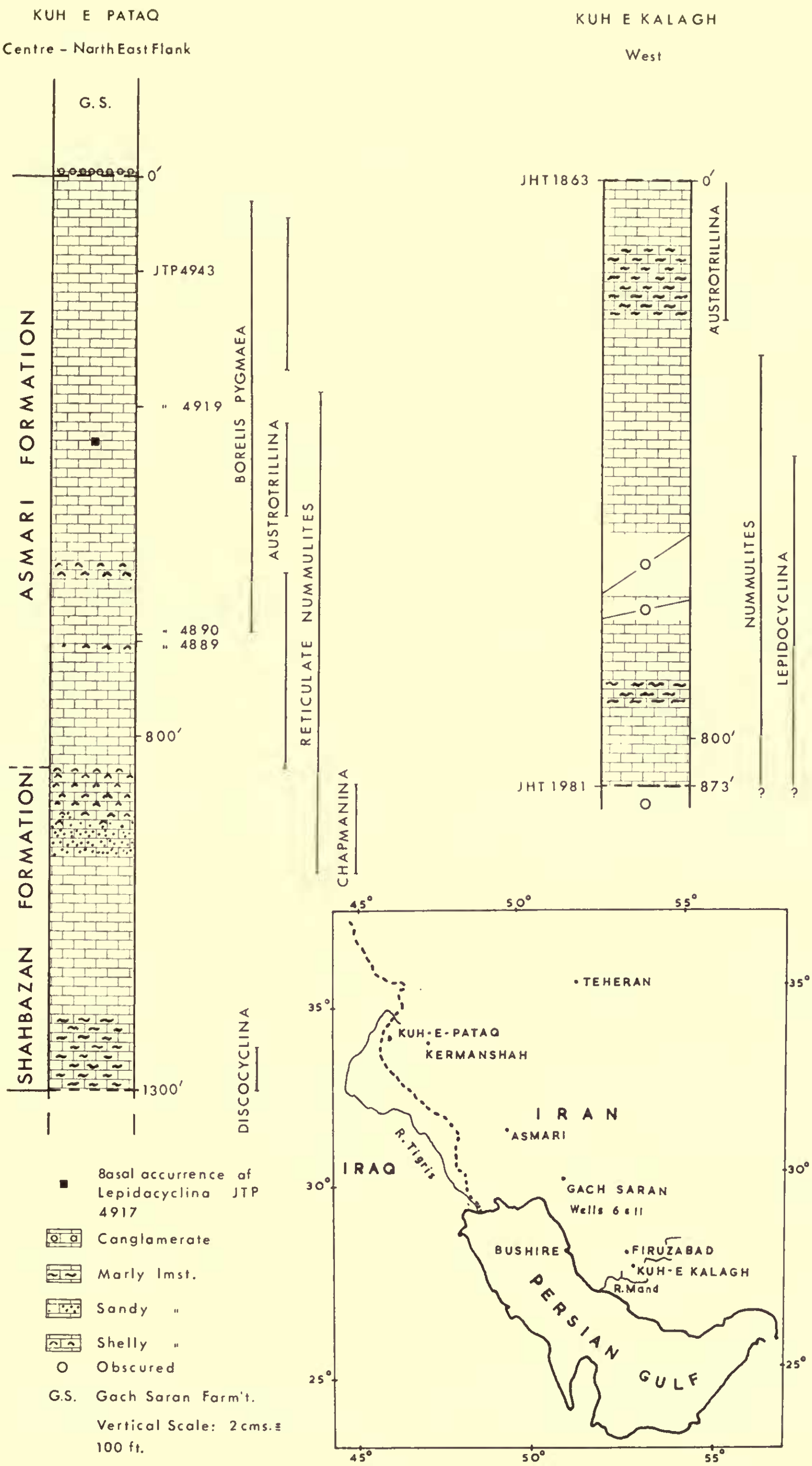


FIG. 2. Two surface sections of the Asmari limestone. Kuh e Pataq is the type locality for *A. asmariensis* sp. nov. Data kindly provided by Dr. T. D. Adams (Iranian Oil Operating Companies). For *Borelis pygmaea* read *Borelis pygmaeus*.

in Well K.14, from which *A. paucialveolata* was first described, is as follows:

Succession	*Age*
Lower Fars conglomerate	Burdigalian
———disconformity———	
Baba Formation (Thickness about 30 ft.) (65 ft. in K109, van Bellen p. 260)	Middle Oligocene (on the association of *Nummulites* and *Eulepidina*). Fore-reef.
———disconformity———	
Shurau Formation (Thickness about 30 ft.) (60 ft. in type section, K109; van Bellen p. 260)	High Lower Oligocene or Middle Oligocene. Types of *A. pauci-alveolata* from here. Back reef.
Sheikh Alas Formation (85 ft. type section; van Bellen p. 260)	Lower Oligocene. *N. fichteli* without *Eulepidina*. Fore reef.

The Bajawan Formation, not represented in Well K14, has as its type locality Well K109 (Baba Dome) where, according to van Bellen, it overlies the Baba limestone conformably, has a thickness of 128 ft. and is developed in " back reef " facies. According to Smout & Eames (1958) the Bajawan Formation is probably Aquitanian in age, but the evidence for this is rather tenuous since it depends largely on the assumption that *Spiroclypeus* does not occur in the Oligocene. It may be noted that van Bellen (1956 : 260) said that the Baba Formation is the fore-reef equivalent of the Bajawan limestone, in which case both are of Middle Oligocene age. On the other hand, van Bellen had not seen *Spiroclypeus* in the Bajawan Formation whereas Smout and Eames had.

3. *Pemba Island*

This sequence was described by Stockley (1927). Morley Davies, who described the Foraminifera in the same publication, recognized the following subdivisions of the Chake-Chake beds which are 100 ft. thick at outcrop.

Upper horizon	*Miogypsina* without *Lepidocyclina*
Middle horizon (Datum Stratum)	*Amphistegina* and *Operculina*
Lower horizon	*Lepidocyclina* with very rare *Miogypsina*

A. howchini was said by Morley Davies to range from " low down to high up " in the Chake-Chake beds. He dated the entire sequence as high Aquitanian or Burdigalian. These beds are here regarded as Lower Tf for reasons which are given later (see p. 88).

4. *The Kirimalai limestone, Ceylon*

This limestone occurs in the northern part of the island on the Jaffna Peninsula. An account of the stratigraphical succession and of the faunas of the Miocene limestones of Ceylon was given by Wayland & Morley Davies (1923). According to these authors, the forminiferal fauna includes *Orbiculina malabarica* (= *Taberina malabarica*), *Sorites* sp., *Alveolinella* (*Flosculinella*) sp. and *Spiroclypeus*? sp. cf. *pleurocentralis*, together with miliolids of various types. They also report the association of *Orbiculina* sp. and *Spiroclypeus orbitoideus* from Minihagalkanda in the south of the island. However, it is not clear whether these species were found in a single sample or whether they occurred at different levels. *A. howchini* and *Taberina malabarica* have been observed together in a thin section of limestone B.M.(N.H.) P22330 from the Wayland collection labelled "North of Pomparippu, N.W. Province, Ceylon."

5. *The Melinau limestone, Sarawak*

The general succession at Melinau is as follows:

Upper Te limestone	1,600 ft.
Lower Te limestone	1,600 ft.
Td limestone	110 ft.
Tc limestone	1,400 ft.
Tb limestone	1,850 ft.

Austrotrillina occurs from highest Td through Te. For full details of this limestone see Adams (1965).

6. *The Pata limestone, South Australia*

This is the youngest Miocene limestone in the Murray Basin, and Ludbrook (1961) has given details of its foraminiferal fauna. She referred it to the highest Burdigalian but, according to Eames *et al.* (1962), its pelagic foraminifera indicate a Lower Burdigalian age. The position of the Pata limestone in terms of the East Indian letter classification is Lower Tf.

7. *The Miocene limestones of Saipan*

Cole (1957) and Hanzawa (1957) have described the foraminifera from large numbers of surface samples collected over the whole island. The geology has been described by Cloud *et al.* (1956). Unfortunately, no good sections were measured and the relative stratigraphical positions of many samples are uncertain from the field evidence. It has been possible to examine the specimens described by Cole (1957) in Washington and Ithaca, and matrix-free individuals have been extracted from two important samples.

8. *The Miocene limestones of Bikini and Eniwetok*

The faunas of these limestones are known only from boreholes, and have been described by Cole (1954; 1958), Todd & Post (1954) and Todd & Low (1960). The types of *A. striata* come from bore 2B on Bikini Island. All the specimens of *Austrotrillina* recovered from these bores have been examined through the courtesy of Miss Ruth Todd and Professor W. Storrs Cole.

9. *The Lower Coralline limestone of Malta*

This limestone is at least 626 ft. thick (House *et al.*, in Bowen-Jones 1961) and is the oldest described rock unit on the island. However, unpublished information (Eames *in. lit.*) shows that this unit is underlain by a miliolid limestone, at least 75 ft. thick, which lacks *Austrotrillina*. The lower Coralline limestone contains, in addition to *Austrotrillina*, *Peneroplis evolutus*, *Praerhapydionina delicata*, *Spiroclypeus blanckenhorni* var. *ornata*, *Lepidocyclina* (*Eulepidina*) *dilatata*, *Lepidocyclina* (*Nephrolepidina*) *tournoueri* and *Miogypsinoides complanatus*. On the basis of this assemblage it has been dated as Aquitanian (Eames *in lit.*). Although this is probably correct, it is impossible to be certain on the present evidence that this fauna is not Upper Oligocene in age. As mentioned above, it is often assumed that *Spiroclypeus* does not occur in the Oligocene of the Mediterranean region, but proof is lacking (see Adams 1967).

10. *The Miocene orbitoidal limestones of Christmas Island*

Jones & Chapman (1900) were the first to describe the foraminifera from these limestones. Their material has been re-examined and additional thin sections prepared from some of the original rock samples. Ludbrook (1965) published further valuable information on the faunas and her material has also been examined. Additional collections were made recently by Mr. J. Barrie (Bureau of Mineral Resources, Canberra) and these are now being studied in conjunction with Dr. D. J. Belford.

Ludbrook (1965) dated the uppermost part of the limestone as Tf on the occurrence in one sample (P33) of *Flosculinella bontangensis*, a species generally thought—but never actually proved—to be restricted to strata of Tf age. Upwards of 500 samples have now been collected from the limestones of the island but only in one locality is there any suggestion of an age younger than Te. In this connection it is noteworthy that P33 also contains *Borelis pygmaeus*, a species characteristic of Tc–Te and unknown from Tf. Ludbrook originally stated that *Austrotrillina howchini* occurred in P33 but this proved to be an error. All Ludbrooks' figured specimens of *A. howchini* (*op. cit.*, pl. 21, figs. 4–6) are good examples of *A. striata*.

11. *Eocene limestones of New Caledonia*

Through the courtesy of Professor M. F. Glaessner and Dr. J. Sigal, numerous thin sections of Eocene limestones from New Caledonia in which *Austrotrillina* sp. nov. was thought to occur (see Tissot & Noesmoen 1958), have been examined. These organisms are now known to be different from *Austrotrillina* and are under investigation by Glaessner & Sigal.

III. SYSTEMATIC PALAEONTOLOGY

Family **MILIOLIDAE** Ehrenberg 1839

Genus ***AUSTROTRILLINA*** Parr 1942

TYPE SPECIES *Trillina howchini* Schlumberger 1893.

(a) *Shell structure*

The shell wall is basically simple and may be regarded as consisting of three parts (Text-fig. 3).

1. A solid porcellaneous layer laid down over the outer surface of a previously formed chamber. This was referred to as a " step " by Grimsdale (1952) who considered it to be of taxonomic importance. It is, in fact, inconstant in thickness,

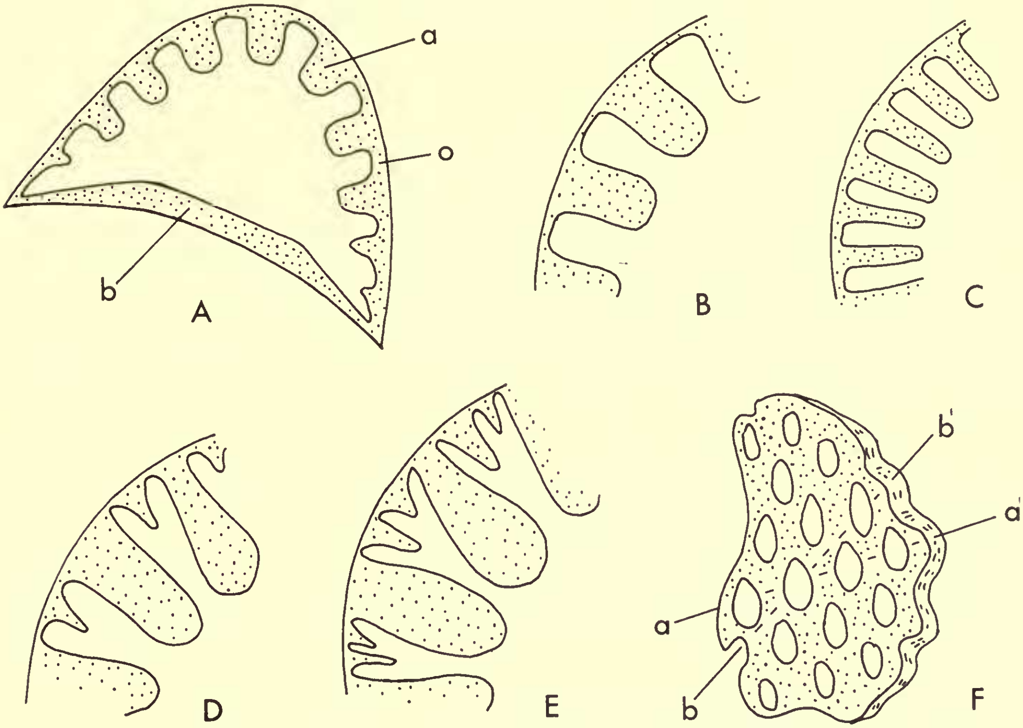


FIG. 3. Wall structure of *Austrotrillina* (drawings all schematic). A. Generalized transverse section through an adult chamber (*a* – alveolar layer; *b* – basal wall or " step "; *o* – outer skin) B. " Striata " type wall with coarse alveoli. C. " Asmariensis " type wall with fine, closely spaced alveoli. D & E. " Howchini " type wall with bifurcating alveoli. E is more advanced than D. F. Wall of *A. striata* seen from inside the chamber. It is clear that the spacing of the alveoli will vary according to the plane of section: a – a′, closely spaced; b – b′, widely spaced. Non-oriented random sections can therefore be misleading. The thickness of the outer skin is greatly exaggerated in these drawings.

both within a species and amongst the specimens from a single assemblage, and is of no taxonomic value.

2. A curved outer wall consisting of two parts:
   (a) a relatively thick, inner alveolar layer;
   (b) a very thin, non-alveolate, outer skin which is punctate externally.

The outer " skin " being very delicate is lost in most individuals. It can be detected only rarely in specimens seen in thin sections of limestone, and then merely as a dark line.

Alveoli may be fine as in *A. asmariensis* or coarse as in *A. striata*. The apparent diameter of the alveoli varies according to the plane of section. This can be verified by examining the inner surface of the wall (Text-fig. 3F; Pl. 4, fig. 12).

In most specimens of *A. striata* and *A. asmariensis*, and in all the known specimens of *A. paucialveolata*, the alveoli are simple tubes. The extent to which they are present throughout the test seems to be a specific character.

In *A. howchini* the wall structure is more complex in that the alveoli bifurcate and trifurcate towards their outer ends, i.e. towards the exterior of the shell (Text-fig. 3D, E), thus producing a pattern of long and short "septa" when seen in cross section. In primitive forms, bifurcation begins at the chamber angles where the wall is thickest, but in the most highly evolved forms the entire wall is involved.

Emended diagnosis. Test free, calcareous, porcellaneous; external wall consisting of a thick alveolar inner part (except for that portion in contact with a previous chamber) and a thin, finely pitted outer skin: chambers one half coil in length: early chambers—in microspheric generation at least—added in quinqueloculine fashion, later chambers usually arranged in triloculine manner so that only three are visible externally. Aperture probably pseudocribrate.

Remarks. The alveolar wall and mode of growth are diagnostic for the genus. The wall may be alveolate back to the second chamber, or the alveoli may be confined to the last few chambers. Previous authors have regarded the triloculine arrangement of the chambers as a constant and diagnostic feature, but this is not the case. It is not unusual to find specimens with four chambers visible externally. It should be noted that the figures given in the Treatise on Invertebrate Paleontology (C474, figs 7, 8), although stated to be of the type species, are actually of *A. striata* Todd & Post.

Todd & Post (1954) described the aperture of *A. striata* as cribrate, while Carter (1964) stated that *A. howchini* has a pseudocribrate aperture. The present material does not permit any comment on apertural characters.

The extremely thin outer skin is preserved only under very favourable circumstances.

(b) *Description of species*

Austrotrillina asmariensis sp. nov.

Pl. 1, figs. 1–12.

?1920 *Trillina howchini* Schlumberger; Silvestri: 77, pl. 4, figs 9, 10.
?1929 *Trillina howchini* Schlumberger; Silvestri: 27, pl. 3, fig. 10.
1937 *Trillina howchini* Schlumberger; Silvestri: 81 (pars), pl. 6, fig. 3, ? pl. 5, fig. 3 only.
1947 *Trillina howchini* Schlumberger; Bursch: 12, pl. 1, figs 1, 2, pl. 3, fig. 14. Not text-fig. 3.
1956 *Austrotrillina howchini* (Schlumberger); van Bellen, pl. 1, figs C, D.
?1957 *Austrotrillina howchini* (Schlumberger); Hanzawa: 38 (pars), pl. 22, figs 12, 13. Not pl. 34, figs 1, 2.
?1957 *Austrotrillina howchini* (Schlumberger); Cole: 329, pl. 101, figs 4–6.
1958 *Austrotrillina howchini* (Schlumberger); Smout & Eames: 208.
?1962 *Austrotrillina howchini* (Schlumberger); Dizer, pl. 3, fig. 7.

TYPE LOCALITY: Kuh e Pataq (46° 00 E. 34° 25′ N.) N.W. Luristan, Iran.

TYPE LEVEL: Oligocene (almost certainly M. Oligocene, but above the last nummulites in the section). Sample JTP 4943.

DIAGNOSIS: An *Austrotrillina* with a simple alveolar wall. Alveoli numerous, normally ranging in diameter from 10 to 20 μ.

HOLOTYPE. P47578.

A FORM

DESCRIPTION. Test comprising a globular or subglobular proloculus 0·07–0·25 mm. in internal diameter, followed by nine to fifteen chambers arranged as for the genus. The chamber walls are rounded, and are alveolate except where in contact with a previous chamber. The alveoli are numerous and simple. The walls of the later chambers are usually 50–80 μ in thickness but occasionally reach 110 μ. All chambers after the second have alveolate walls. The nature of the aperture is unknown.

Dimensions of the holotype

Length : unknown
Diameter : 1·10 × 1·78 mm.
Proloculus diameter: 0·2 × 0·18 mm.

Most specimens are relatively short (about 1 mm., few exceed 1·5 mm. in length), and are between 0·5 and 1·0 mm. in diameter. Very compressed specimens, and rare individuals in which the last chamber has been added at 180° to the penultimate chamber, may be wider than this.

Variation. The shape of the test is not constant. Chambers margins are usually bluntly rounded; many specimens are rather flattened or triangular in cross section. Proloculus diameter is very variable, specimens from the Middle Oligocene sometimes having proloculi with a larger internal diameter than that of any other species.

B FORM

This differs from the A form in having more chambers (12–17 or more), a much smaller proloculus, of which no measurements have been obtained, and a thicker wall in the later chambers. The largest specimen so far seen is 2·3 mm. in diameter. The last-formed chambers are more triangular in cross section than are those of the A forms. The wall attains a maximum thickness of about 0·15 mm.

VARIATION: Two specimens show a tendency for the alveoli to bifurcate in the last two chambers.

ASSOCIATED FAUNA: 1. Type level: *Peneroplis evolutus, P. thomasi, Praerhapydionina delicata.*

2. Lower levels (according to Dr. T. D. Adams): *Archaias asmaricus, Borelis, Eulepidina, Nummulites fichteli, Meandropsina anahensis.* The occurrence of *A. asmaricus* and *M. anahensis* so low in the Tertiary requires verification.

REMARKS: This species has frequently been confused with *A. howchini* in the past, and many records of the latter from the Middle and Far East really refer to *A. asmariensis*.

The earliest definite occurrence of the species is in the Asmari Formation at Kuh e Pataq where it occurs in beds which, on the available evidence (see p. 76), can be assigned tentatively to the Lower Oligocene. It occurs commonly in the Middle Oligocene of the same section and in the Shurau Formation of Iraq, which is also M. Oligocene; good specimens have been found in two museum samples from surface exposures in Iran, in each case in association with *Nummulites fichteli*, an indication that these rocks cannot be younger than Middle Oligocene and could be Lower Oligocene in age. Neither sample contained *Lepidocyclina*.

In the Shurau Formation *A. asmariensis* is often associated with *A. paucialveolata*. It occurs abundantly in the Bajawan Formation of Iraq and in derived pebbles in the lower part of the Lower Fars conglomerate: it is common in the middle part of the Asmari limestone.

Silvestri's records from Somalia (1937), said to be from the Oligocene or Miocene are, in part at least, from the Oligocene. Of his illustrated specimens. pl. 5, fig. 2, is a largely recrystallized form which might fairly be assigned to *A. paucialveolata;* pl. 5, fig. 3 is not very clear, but pl. 6, fig. 3 is almost certainly *A. asmariensis*. In no case were these specimens associated with an age-diagnostic fauna, nor were they from successions the ages of which could be determined with certainty.

Records of *A. howchini* (Silvestri 1920, 1929) from the island of Paxos and from Otranto, Apulia, southern Italy, probably refer to this species, although the figures are not really good enough for this to be certain.

Dizer (1962) has recorded *A. howchini*, from beds of supposed Burdigalian age in various parts of N.W. Turkey. Unfortunately, her best illustration is almost indeterminable as details of the wall structure cannot be seen. However, the shape of the chambers strongly suggests that the specimen is *A. asmariensis*. Dizer's other illustration (pl. 1, fig. 16) is unrecognizable owing to poor preservation.

Specimens indistinguishable from *A. asmariensis* are frequently met with in random sections of limestones from the Indo-Pacific where they occur at about the same levels as *A. striata*. They apparently occur in all the known Te limestones of Sarawak and have been seen in the Te limestones along the Kinabatangan River in Sabah and in Te limestones from Saipan (see p. 93). They occur in the Melinau limestone and were referred to the *A. striata/howchini* group by the author (1965).

A. asmariensis differs from typical specimens of *A. paucialveolata* and *A. striata* in having an inner wall that is clearly alveolar back to the third chamber in the A form. It differs from *A. striata* in having more numerous and much smaller alveoli. It differs from *A. howchini* in having simple (i.e. non-bifurcating) alveoli, a thinner wall and a more open chamber lumen in the adult stage (see Table 1).

GEOGRAPHICAL DISTRIBUTION: Middle East, East Africa, south-east Asia, Pacific Islands.

STRATIGRAPHICAL RANGE:? Lower or Middle Oligocene to Lower Miocene in the Tethyan region: Te in the Indo-Pacific region.

Note: Although typical specimens of *A. asmariensis* and *A. striata* (cf. Pl. 1, figs 4, 7, 11, and Pl. 4, figs 11, 4, 13) look very different, the geographical and stratigraphical distributions of the two are such that it is difficult to avoid the conclusion that we are really dealing with one species and that the differences between them are not of fundamental importance. Nevertheless, pending the discovery of matrix-free specimens of *A. asmariensis* and a concomitantly more detailed description, it is advisable to regard it as a distinct species.

Austrotrillina brunni Marie

Pl. 6, figs 6, 8

1955 *Austrotrillina brunni* Marie: 203, pl. 19, figs 4–8.

REMARKS. The only record of this species is from a limestone a few metres thick within " une immense succession gréseuse " to the north-west of the village of Pentafolon in north-west Greece. The limestone was dated as Upper Oligocene or basal Aquitanian on the occurrence of *Miogypsinoides complanatus* (Schlumberger). The only other foraminifera listed from it are *Lepidocyclina* (*Nephrolepidina*) sp., which occurs in abundance, and *Rotalia* sp.

It has not been possible to examine the thin sections in which this species was found, but Dr. P. Marie has kindly made available the original photographs on which the figures on pl. 19 of his paper were based. The reproduction of these photographs in Marie's paper is, unfortunately, not good enough for the internal structure to be clearly discerned. However, the photographs show that the structure of the wall is, in some specimens at least, fairly advanced in type, i.e. the alveoli bifurcate towards their outer ends. On the other hand, in other specimens there is no sign of bifurcation, and these resemble the *A. striata/asmariensis* group. In all specimens the chambers are rounded in cross section and in this respect are unlike the Australian representatives of *A. howchini*. They resemble forms found in Upper Te in the Indo-Pacific region, i.e. they are intermediate between the *A. striata/asmariensis* group and the true *A. howchini*.

On the present evidence it is impossible to assign an accurate age to the Pentafolon limestone. The wall structure of the *Austrotrillina* specimens suggests that the rock is late Aquitanian in age. The presence of *M. complanatus* is not a sufficient indication of age since it ranges from the Oligocene into the early Miocene. Its upper limit does not appear to have been established satisfactorily. Eames (*in lit.*) has indicated that *M. complanatus* is common in late Aquitanian beds in the Middle East; Renz (1936) recorded it from Italy with *Miogypsina irregularis* (Michelotti) (= *M. globulina* (*Michelotti*)) a species usually considered to be " Burdigalian " in age, and Gordon (1961) has reported it from " above the *Orbulina* surface ", i.e. from " Burdigalian " or younger rocks, in Puerto Rico. A further examination of the limestone is necessary to establish whether or not it contains foraminifera that would substantiate an Aquitanian age.

Marie believed that the rounded nature of the chambers and, therefore, of the test, was sufficient to distinguish this species from *A. howchini*. The present author does not share this view. While the youngest Australian representatives of *A. howchini* have triangular chambers, many advanced Tf forms from New Guinea, East Africa and India have rounded chambers. Marie also laid emphasis on the quinqueloculine arrangement of the chambers in *A. brunni*. They are, however, more triloculine than quinqueloculine and are similar to those of *A. striata*, a species which often shows four chambers externally (see Pl. 4, fig. 9).

It is thought that the name *A. brunni* should be retained until such time as oriented sections made from additional material can be compared with sections of other species of the genus.

Austrotrillina howchini (Schlumberger)

Pl. 2, figs 1–7; Pl. 6, figs 1–5, 7

1893 *Trillina howchini* Schlumberger; 119, text-fig. 1, pl. 3, fig. 6.
1908 *Trillina howchini* Schlumberger; Chapman: 753, pl. 39, figs 7–9.
1913 *Trillina howchini* Schlumberger; Chapman: 169, pl. 16, fig. 4.
1927 *Trillina howchini* Schlumberger; Davies: 10, pl. 2, figs 10, 11.
?1927 *Trillina howchini* Schlumberger; van der Vlerk & Umbgrove: 13, text-fig. 2.
1936 *Trillina howchini* Schlumberger; Renz: 32, pl. 15, figs 4, 5.
1936 *Trillina howchini* Schlumberger; Crespin: 6, pl. 1, figs 1, 2.
1941 *Trillina howchini* Schlumberger; Rao: 7, pl. 2, fig. 7.
1942 *Austrotrillina howchini* (Schlumberger); Parr: 361–2, figs 1–3.
1954 *Austrotrillina howchini* (Schlumberger); Crespin: 40, pl. 7, fig. 14.
1955 *Austrotrillina howchini* (Schlumberger); Crespin: 60–1, pl. 9, fig. 4.
?1957 *Austrotrillina howchini* (Schlumberger); Hanzawa: 38 (pars), pl. 34, figs. 1, 2. Not pl. 22, figs 12, 13.
1962 *Austrotrillina howchini* (Schlumberger); Eames *et al.*, pl. 6, figs B, E.
1964 *Austrotrillina howchini* (Schlumberger); Carter: 62, pl. 1, figs 12–17.

DIAGNOSIS. An *Austrotrillina* with a smooth, finely pitted test; wall thick, with closely spaced alveoli which bifurcate—sometimes more than once—towards their inner ends to form secondary and tertiary alveoli.

A FORM

DESCRIPTION. Test comprising a subglobular proloculus (0·07–0·15 mm. in diameter) followed by a tube-like second chamber; subsequent chambers arranged in a triloculine manner so that not more than three are visible externally. The shell normally consists of from ten to twelve chambers (proloculus excluded). The non-alveolar outer skin is very thin (5–10 μ) and is covered with fine, shallow pits. The inner layer is thick, alveolate, the alveoli bifurcating as they approach the outer skin so that primary, secondary and tertiary alveoli appear. The dividing walls between the secondary and tertiary alveoli are always much shorter than the primary dividing walls and thus appear as short " septa " in transverse sections. The alveoli make a sharp turn as they reach the outer skin and end blindly (Pl. 2, fig. 6). Transverse sections cut through the upturned ends of the alveoli produce the impression of vertical canals (Pl. 2, fig. 3). The alveolar layer is always thickest at the chamber angles; it often occludes much of the chamber lumen. The aperture is pseudocribrate according to Carter (1964).

B FORM

Only one specimen available.

Similar to the A form but with a much smaller proloculus. Test composed of at least sixteen chambers.

MEASUREMENTS: length: not recorded, but not noticeably greater than that of the A form

diameter: 2·14 × 1·35 mm.

wall thickness: 0·17–0·35 mm.

VARIATION: In most specimens, especially those from Australia, the chambers are triangular in shape rather than rounded.

REMARKS. Schlumberger described the A form of this species from Muddy Creek, Hamilton, Victoria, southern Australia, and the B form from the Philippines. However, in the absence of an adequate figure and description of the latter form there is no certainty that he was describing the same species. Carter (personal communication) has recently confirmed that it is impossible to tell either the exact locality or the horizon from which Schlumberger's Australian specimens came. The only beds in Victoria from which matrix-free specimens can now be obtained are poorly exposed at Gippsland.

Most of the specimens described here come from the Pata limestone, penetrated in a boring at the Chowilla Dam Site, River Murray, South Australia. Ludbrook (1961; 1963) assigned this limestone to the uppermost Burdigalian on the ground that it contained *A. howchini* together with *Orbulina universa.* It is thus approximately that same age as the Trealla limestone in West Australia. Ludbrook (1963) also notes that *A. howchini* occurs with *Flosculinella bontangensis* (Rutten) and *Marginopora vertebralis* Blainville (the former is a typical Lower Tf or " Burdigalian " species) in the Nullarbor limestone of the Eucla Basin, South Australia.

A. howchini has been recorded fairly frequently from the Miocene of Australia and is known from the Cape Peninsula in the west (Crespin 1955) to Victoria in the south. It occurs in beds of Lower Tf age in the Tulki and Trealla limestones of west Australia. In the Trealla limestone it is associated with *Orbulina universa* as well as with numerous other Tf marker fossils. In Victoria (Carter 1964) it appears two zones below *Orbulina universa* and *O. suturalis* and gives its name to a zone.

Most records of *A. howchini* from outside Australia are, unfortunately, incorrect. The only occurrences known to the writer that can be properly substantiated are as follows.

1. *Lower Miocene limestones of the Malabar coast. Cochin, Travancore, India.* In these limestones *A. howchini* occurs together with *Taberina malabarica.* These beds were said by Carter (1853) to be Pliocene in age, but the foraminifera prove otherwise. Carter did not mention *A. howchini*, but it is a common species in his samples (see pl. 6, figs 2, 4, 5). It also occurs in Miocene conglomerates in the Tapti area, western India (Rao 1941).

2. In the Lower Miocene limestones of Ceylon, *A. howchini* occurs with *Taberina malabarica.* Wayland & Davies (1923) also reported *Flosculinella* and *Spiroclypeus* from these limestones. The latter genus was stated to be represented by two speci-

mens. It does not occur in any of the three slides deposited in the British Museum (Natural History), neither has it been found in additional samples recently examined. Its occurrence in this limestone is therefore open to doubt. The specimens referred by Davies to *Flosculinella* are very poorly preserved and may or may not belong to this genus. The evolutionary stage reached by the wall structure of the *Austrotrillina* specimens from these samples allows the rock to be dated as Lower Tf or " Burdigalian ". *Flosculinella* commonly occurs in strata of this age whereas *Spiroclypeus* does not.

3. *Lower Miocene limestones of East Africa: A. howchini* occurs with *T. malabarica, Miogypsina thecidaeformis* and *Miogypsinoides dehaarti* in the Lower Chake beds of Pemba Island, and with *T. malabarica* in beds of a similar age in the Hadu-Fundi Isi area of Kenya. Following the recent discovery of *Flosculinella bontangensis* in the Chake Chake beds (Eames *et al.* 1962) these can be regarded as Lower Tf in age. *F. bontangensis* alone, cannot as yet be considered as diagnostic of Tf, but in the light of the evidence presented in this paper its occurrence with *A. howchini* s. s. does constitute a satisfactory indication of age.

4. *The Melinau limestone, Sarawak:* In the uppermost part of this limestone (Upper Te) specimens transitional from *A. asmariensis* to *A. howchini* occur (Pl. 5, figs 1, 4). Planktonic foraminifera, including *Praeorbulina* cf. *glomerosa* (Blow), occurring in samples collected in 1966 from the highest beds in the Terikan River, indicate that the top of the limestone is in Zone N8 of Banner & Blow (1965) and not in the *C. dissimilis* Zone as previously suggested (Adams 1965). Primitive representatives of *A. howchini* have also been seen in bore-hole material from the Suai Baram area, Sarawak.

5. *Saipan:* A problem arises in connection with the fauna of the Tagpochau limestone. Cole (1957) regarded this limestone as Te in age while Hanzawa (1957) thought that at least part of it was Tf. Hanzawa (1957, table 2, sample g; table 4, sample 3) reported *Spiroclypeus tidoenganensis* and *Orbulina universa* as occurring together in samples from Saipan and Tinian. However, an examination of the very numerous Miocene samples from Saipan deposited in the U.S. National Museum has failed to reveal *Orbulina* in association with *Spiroclypeus*. Reasonable doubt therefore exists about the accuracy of some of Hanzawa's determinations of one or other of these genera. Both *A. striata* and *A. howchini* occur on Saipan. The former species is the more common, the latter occurring only in a small number of samples (e.g. B413).

Although the common species in Saipan is *A. striata*, specimens indistinguishable from *A. asmariensis* are sometimes seen in random thin sections. This is also true of the Bornean limestones. Whether this means that *A. asmariensis* and *A. striata* are really synonymous, or that the range of variation of some characters overlaps is not clear. However, when total assemblages are considered there is no difficulty in deciding which species is present.

6. *Pacific Isles:* Todd & Low (1960) stated that *A. howchini* occurred in the upper part (1100–1110 ft.) of Eniwetok drill hole E–1 and from 560–570 ft. in F–1.

These authors kindly allowed the writer to examine and section the specimens on which their identification was based. This study showed that the two lowest specimens should have been referred to *A. striata* and the highest to " miliolid *gen.* et *sp.* indet." Similarly, the specimens described as *A. howchini* by Todd & Post (1954) from Bikini are also incorrectly identified. It should be said that these identifications were based on the external appearance of the tests, all of which were decorticated. We now know that external appearances can be misleading, but this was not known when the Bikini and Eniwetok bores were first examined. It can therefore be stated that no specimens of *A. howchini* are known from the Pacific Isles east of Saipan although it is probably only a matter of time before they are discovered.

Most records of *A. howchini* from the Far East are impossible to verify as they are unaccompanied by figures. However, it is probable that all records of *A. howchini* from beds of Tf age can be accepted as correct, except where the dating depends on the presence of *Austrotrillina*. This is certainly true of New Guinea where excellent examples of *A. howchini* occur in Tf limestones. Records from beds of Upper Te age cannot be accepted at their face value unless accompanied by figures: records from beds of Td and Lower Te age are almost certainly incorrect, and in all probability refer either to *A. asmariensis* or to *A. striata.*

7. *Europe and the Middle East:* The only definite record of *A. howchini* from Europe appears to be that of Renz (1936) who reported it from the Burdigalian of the central Apennines. His specimens have been examined. *Austrotrillina brunni*, from the Lower Miocene of Greece is not, of course, far removed from *A. howchini* and is very probably a transition form from *A. striata* (see below). The specimens illustrated by Silvestri (1920, 1929) seem to have a simpler wall structure than *A. howchini s. s.* Hottinger's record (1963) of this species from the Oligocene of Spain is really of *A. paucialveolata.*

Dizer's record (1962) of *A. howchini* from the Miocene of the Sivas Basin, Turkey, is almost certainly incorrect as was indicated earlier (p. 84).

Stefanini's record (1921 : 124) of *A. howchini* from the Oligocene of Cyrenaica is unacceptable as his figured specimen is not even recognizable as *Austrotrillina.* The writer has, however, seen specimens of the *A. striata/asmariensis* type from early Miocene deposits of Libya.

GEOGRAPHICAL DISTRIBUTION: Known from Europe, East Africa, India, Indonesia, New Guinea, Saipan and Australia.

STRATIGRAPHICAL DISTRIBUTION: Mainly Lower Tf (= " Burdigalian " of Europe). Transitional forms from *A. striata* and *A. asmariensis* occur in Upper Te beds of south-east Asia and Saipan.

Austrotrillina paucialveolata Grimsdale

Pl. 3, figs 1–6

?1937 *Trillina howchini* Schlumberger; Silvestri (pars): 81, pl. 5, fig. 2.
1952 *Austrotrillina paucialveolata* Grimsdale: 229, pl. 20, figs. 7–10.
1956 *Austrotrillina paucialveolata* Grimsdale; van Bellen, pl. 3, fig. A, pl. 6, fig. B.

?1962 *Austrotrillina paucialveolata* Grimsdale; Dizer: 43–4, pl. 2, figs 1, 2.
1963 *Austrotrillina howchini* (Schlumberger); Hottinger: 964, pl. 1, figs 1, 2.

Emended diagnosis. An *Austrotrillina* with simple alveoli restricted to the last few chambers.

A form

Description. Test comprising a proloculus, a tube-like second chamber and up to fourteen further chambers arranged roughly in a triloculine fashion. The alveoli are simple and appear to be confined to the last four to six chambers. The diameter of the proloculus ranges from 0·08 to 0·13 mm. in the few specimens measured. The nature of the aperture and the surface appearance of the test are unknown.

B form

Only a few off-centre sections available. Larger than the A form, and presumably with more chambers. Maximum number of chambers observed is thirteen. Wall up to 0·15 mm. thick. Maximum observed diameter 2·15 mm.

Remarks. The original description of this species is extremely short and has not previously been emended. Grimsdale only stated that the alveoli were coarser than in *A. howchini*. However, the specimens he had in mind when making this comparison were not *A. howchini s. s.* but *A. asmariensis* sp. nov. as is shown below. After examining Grimsdale's syntypes, specimens from the Iraq Petroleum Company's collections in London, and large numbers of thin sections from the Asmari limestone in the Gach Saran oilfield (Gach Saran wells 6 and 11) and from Kuh e Pataq and Kuh e Kalagh, the following conclusions have been reached:

1. All the specimens of *A. paucialveolata* so far described from the type area are poorly preserved, and the apparent coarseness and irregularity of the alveoli is due in all cases to poor preservation caused by recrystallization of the limestone and of the shell walls.
2. Grimsdale's specimens included both A and B forms although he appears to have been unaware of this. The two largest figured syntypes were probably both B forms.
3. The " step " described by Grimsdale is a thickening of the basal wall. It is not a constant character but varies in development amongst specimens from the same population. It is very prominent in some individuals of *A. striata* (Pl. 4, fig. 13) and *A. howchini* (Pl. 2, fig. 3), and occurs to some extent in all representatives of the genus.
4. *A. paucialveolata* occurs with *A. asmariensis* (= *A. howchini sensu* Grimsdale and van Bellen) in the Lower Asmari limestone.
5. The only diagnostic features of this species seem to be the restriction of the alveoli to the last few chambers, coupled with the fact that the walls of the early chambers appear to be thick. These features could, however, be recrystallization effects.

6. There is no evidence as yet that *A. paucialveolata* occurs at stratigraphically lower levels than *A. asmariensis.* However, since it has not so far been reported above the Middle Oligocene it is worth regarding as separate from *A. asmariensis* for the present.

If future work on isolated, matrix-free specimens shows conclusively that *A. paucialveolata* and *A. asmariensis* are synonymous, then the former name will have priority regardless of the fact that it will be inappropriate descriptively.

Grimsdale (1952) described this species from the Miliola limestone of the Kirkuk oilfield, Iraq, stating in his plate explanation that the syntypes came from Kirkuk Well no. 14. No depth or horizon was given. The age was stated to be Oligocene, but from the information given in his text (p. 224) it is impossible to deduce whether it is Lower, Middle or Upper Oligocene. Although not specifically stated, the implication is that the Miliola limestone is younger than Lower Oligocene since it rests on beds of undoubted Lower Oligocene age.

Van Bellen (1956) described Kirkuk Well 14 in detail, and figured additional specimens of *A. paucialveolata.* Examination of van Bellen's plate revealed that among the ten specimens figured were the three original syntypes of Grimsdale. Van Bellen was apparently unaware of this as he made no mention of it in the text. This refiguring is extremely fortunate since it fixes the exact horizon of the types as 34 feet below the Lower Fars Conglomerate, i.e. in the Shurau Formation. This Formation in Kirkuk Well 14 is only thin, 30 ft. at most, whereas in the type section (Well K109) it is 60 ft. thick. From van Bellen's paper it seems probable that the Shurau Formation is of late Lower Oligocene age, since it conformably overlies the Sheikh Alas Formation of undoubted Lower Oligocene age (contains *Nummulites fichteli* without *Eulepidina*) and is itself disconformably overlain by the Baba Formation—presumably Middle Oligocene in age since it contains both *N. fichteli* and *Lepidocyclina* spp.

Silvestri's (1937) record of this species was discussed by Grimsdale (1952) and nothing further can be added here. The only other record from the Middle East seems to be that of Dizer (1962). Her figures are obviously of poorly-preserved specimens and she gives no description.

It is significant that the material described by Grimsdale and van Bellen came from the same well, and it is even more significant that van Bellen recorded *A. howchini* (really *A. asmariensis* sp. nov. or *A. striata*) from the same level in this well. In correspondence, Dr van Bellen has confirmed that *A. paucialveolata* and the species he called *A. howchini* are known in association in at least two other wells.

The only reliable record of *A. paucialveolata* from outside the Middle East is that of Hottinger (1963) who recorded it as *A. howchini* from the Oligocene of Spain. Hottinger's specimens have been examined and two of them are figured here (Pl. 3, figs 5, 6).

GEOGRAPHICAL DISTRIBUTION: Iraq, Iran, Spain, Turkey.

STRATIGRAPHICAL RANGE: Only known with certainty from the highest part of the ? Lower Oligocene or from the Middle Oligocene of the Middle East, and from the Oligocene (? Middle Oligocene) of Spain.

Austrotrillina striata Todd & Post

Pl. 4, figs 1–13 ; Pl. 6, fig. 9

1954 *Austrotrillina striata* Todd & Post: 555, pl. 198, fig. 9.
1954 *Austrotrillina howchini* (Schlumberger); Cole: 573, pl. 210, figs. 6–9.
1960 *Austrotrillina striata* Todd & Post; Todd & Low: 825, pl. 261, fig. 22.
1965 *Austrotrillina howchini* (Schlumberger); Ludbrook: 292, pl. 21, figs. 4–6.

Diagnosis: A species of *Austrotrillina* distinguished by its simple, coarse alveoli and finely striate surface.

A form

Description: Test comprising a spherical proloculus (0·05–0·13 mm. in diameter) followed by up to sixteen chambers arranged in a quinqueloculine fashion. The inner layer of the wall is thick and does not become markedly alveolate until the fifth or sixth chamber. The alveoli are mainly simple and are coarse. Their apparent width, seen in thin section, depends on the plane through which the wall is cut (see Text-fig. 3 F, pl. 4, fig. 12). The lumen of the chambers remains open throughout the adult stage. The outer, non-alveolate, skin is very thin (10–15 μ), finely pitted, and ornamented by fine striae which tend to become coarser on the apices of the external margins. Wall thickness ranges from 0·06–0·11 mm. (usually 0·06–0·08 mm.). The chambers are rounded in transverse section. Many topotype specimens are only weakly striate, a few are possibly non-striate. Aperture cribrate according to Todd & Post (1954).

B form

Pl. 5, fig. 9, (not from type area).

Diameter: 1·28 × 0·78 mm.

Wall thickness: 0·08–0·18 mm.

Proloculus diameter: 0·025 mm. Nineteen chambers visible.

Remarks: The original figures of this species are somewhat misleading in that they show only a few relatively coarse striae in the centre of the test. Inspection of numerous topotypes has shown that in typical specimens the whole wall is very finely striate (Pl. 4, fig. 9). This species was originally said to differ from *A. howchini* in its striated surface, much coarser textured alveoli, and in being less distinctly triangular in transverse section. No thin section showing the wall structure was figured. Cole (1954), in a companion publication in the same volume, figured thin sections of a form he called *A. howchini* from the same levels in the Bikini drill hole as the types of *A. striata*. These specimens have been examined and there is no doubt that most of them are examples of *A. striata*.

As mentioned earlier, Cole's figures were, unfortunately, reproduced in good faith by Loeblich & Tappan as *A. howchini*. It should be noted that the surface striae do not show up in thin sections. The alveoli in Cole's specimens are very like those seen in some individuals of *A. asmariensis*. In a few specimens there is a tendency for the alveoli to bifurcate (Pl. 3, fig. 9), but this is not pronounced or common. Such individuals are intermediate between *A. striata* and *A. howchini*.

GEOGRAPHICAL DISTRIBUTION: The Pacific Isles, Indonesia, Christmas Island, i.e. Indo-Pacific. Perhaps also the Tethyan region. Specimens seen by the writer from the Lower Coralline limestone of Malta (Pl. 3 fig. 7) are best referred to as *A.* cf. *striata* for the time being.

STRATIGRAPHICAL RANGE: Uppermost Td and throughout Te in the Indo-Pacific. Uncertain in the Tethyan region, but probably Upper Oligocene and lowermost Miocene (Aquitanian).

Limestones of Upper Te age in Borneo, Saipan and Christmas Island all contain *Austrotrillina* specimens that are morphologically intermediate between *A. striata* and *A. howchini*. True specimens of *A. striata* always occur in the same populations. There can be no doubt that *A. howchini* evolved from *A. striata* in Upper Te times.

(c) *Outstanding problems*

1. Detailed descriptions of *A. asmariensis, A. paucialveolata* and *A. brunni* based on matrix-free specimens are necessary. Until these become available it will be impossible to decide the exact relationships of these species to each other and to *A. striata*.

2. More precise information is needed on the ranges of all the species. In particular, it would be interesting to know whether or not *A. asmariensis* and *A. paucialveolata* occur in undoubted Lower Oligocene beds outside the Middle East.

IV. CONCLUSIONS

On present evidence it is possible to recognize five species of *Austrotrillina* in rocks of ? Lower or Middle Oligocene to Lower Miocene age. The type species, *A. howchini*, has a more complex wall structure than the others and represents the end point in the evolution of the genus. Two species, *A. brunni* and *A. paucialveolata*, are poorly known and of uncertain stratigraphical value. The others are extremely useful for correlation.

The most important characters for species differentiation are (a) the structure of the inner wall and (b) the type of surface ornament. In all other respects the tests are remarkably similar, a fact that may be taken to indicate a monophyletic origin for the genus. There seem to be no significant differences in the size of test, diameter of the proloculus or number or arrangement of chambers between the species. The distinguishing characters for the various species are set out in Table 1.

The identification of species of *Austrotrillina* is a relatively simple matter provided that preservation is reasonably good and that oriented sections, or a sufficient number of random sections, are available. It is, however, dangerous to try to distinguish between *A. asmariensis, A. paucialveolata* and *A. striata* on badly preserved material or on rare random sections in limestones. Members of the Miliolidae are amongst the first foraminifera to be affected by recrystallization, and *Austrotrillina*, because of its alveolar wall, is particularly prone to partial destruction.

TABLE I

Key for identification of species of *Austrotrillina*—A forms only.
Data on size of test, proloculus diameter, number of chambers, not included as no significant differences were observed.

	A. asmariensis	*A. brunni*	*A howchini*	*A. paucialveolata*	*A. striata*
Ornament	smooth ?	?	smooth, but surface finely pitted: sub-surface reticulum visible when wet.	smooth ?	finely striate and finely pitted.
Alveoli	simple; closely spaced	simple or bifurcating	birfurcating; often very complex	simple; irregular ? or like *striata*	simple; widely spaced.
Extent of alveolar layer	throughout test	uncertain: probably throughout test	throughout test	restricted to last few chambers	probably throughout test but usually not seen in early chambers
Number of alveoli/100 μ Measured in oriented cross sections	3 or more	———	———	irregular ?	2–3
Total thickness of wall in adults	usually 50–80 μ; rarely up to 110 μ.	thick	thick: 70–290 μ often 200 μ or more at chamber angles	60–70 μ	60–110 μ
Thickness of outer skin	thin: about 10 μ	?	5–8 μ	?	10–15 μ
Chamber lumen	open	open	much reduced	open	open
Cross-sectional appearance of chambers	rounded	rounded	triangular or rounded	rounded or bluntly triangular	rounded

Austrotrillina appeared in the Oligocene of the Middle East, its first recorded occurrence being with *Nummulites fichteli*. The earliest known forms can be assigned to *A. asmariensis*. In the Shurau Formation of Iraq, *A. asmariensis* occurs alongside *A. paucialveolata*. The latter species does not appear to have achieved a wide geographical or stratigraphical distribution; it is based on recrystallized or otherwise badly preserved specimens and may eventually prove to be synonymous with *A. asmariensis* or *A. striata*.

A. asmariensis persisted virtually unchanged from the Middle Oligocene into the Lower Miocene (Aquitanian). In the Indo-Pacific, *A. striata* appeared in late Td times and persisted through Te. It is possible that these are two forms of the same species.

Present evidence indicates that the transition from *A. striata* to *A. howchini* began in Upper Te times in the Indo-Pacific and that this process was complete by Tf times. In Lower Tf times (" Burdigalian " in the Tethyan region) all known representatives of the genus were of the advanced *A. howchini* type. This last species was widely distributed, ranging from the western Tethys to Australia.

The writer believes that all the species of *Austrotrillina* belong to a single lineage and that, in a sense, they all belong to one species. The evolutionary changes shown by the test will allow us to delimit a number of " species " which are of value stratigraphically. These specific names should be maintained for as long as they can be shown to be of stratigraphical value.

V. REFERENCES

Adams, C. G. 1965. The Foraminifera and stratigraphy of the Melinau limestone, Sarawak and its importance in Tertiary correlation. *Q. Jl. geol. Soc.*, London, **121** : 283–338, pls. 21–30.

—— 1967. Tertiary foraminifera in the Tethyan, American and Indo-Pacific Provinces. Pp. 195–217. In: *Aspects of Tethyan Biogeography*, Eds. C. G. Adams & D. V. Ager, Systematics Association Publication No. 7, London. 336 pp.

Banner, F. T. & Blow, W. H. 1965. Progress in the planktonic foraminiferal biostratigraphy of the Neogene. *Nature*, London, **208**: 1164–1166.

Bellen, R. C. van 1956. The stratigraphy of the " Main Limestone " of the Kirkuk, Bai Hassan and Qarah Chauq Dagh structures in north Iraq. *J. Inst. Petrol.*, **42**, no. 393: 233–263, 8 pls.

Bursch, J. G. 1947. Mikropaläontologische Untersuchungen des Tertiärs von Gross Kei (Molukken). *Schweiz palaeont. Abh.*, **65** : 1–69, pls. 1–5.

Carter, A. N. 1964. Tertiary Foraminifera from Gippsland, Victoria, and their stratigraphical significance. *Mem. geol. Surv. Vict.*, **23** : 1–154, 17 pls.

Carter, H. J. 1853. Description of *Orbitolites malabarica*, illustrative of the spiral and not concentric arrangement of chambers in d'Orbigny's Order Cyclostègues. *Ann. Mag. nat. Hist.*, London (2) **11** : 142–144, pl. 11A.

Chapman, F. 1908. On the Tertiary limestones and foraminiferal tuffs of Malekula, New Hebrides. *Proc. Linn. Soc. N.S.W.*, **32** : 745–760, pls. 37–41.

—— 1913. Description of new and rare fossils obtained by deep boring in the Mallee. Part 1—Plantae; and Rhizopoda to Brachiopoda. *Proc. R. Soc. Vict.* (n.s.) **26** : 165–191, pls, 16–19.

COLE, W. S. 1954. Larger foraminifera and smaller diagnostic foraminifera from Bikini drill holes. *Prof. Pap. U.S. geol. Surv.*, **260–0** : 569–608, pls. 204–222.

—— 1957. Larger foraminifera of Saipan Island. *Prof. Pap. U.S. geol. Surv.*, **280–1** : 321–360, pls. 94–118.

—— 1958. Larger foraminifera from Eniwetok Atoll drill holes. *Prof. Pap. U.S. geol Surv.*, **260–v:** 743–784, pls. 231–249.

CLOUD, P. E., SCHMIDT, R. G. & BURKE, H. W. 1956. Geology of Saipan, Mariana Islands. *Prof. Pap. U.S. geol. Surv.*, **280A** : 1–126.

CRESPIN, I. 1936. The larger foraminifera of the Lower Miocene of Victoria. *Palaeont. Bull., Canberra,* **2** : 3–13, pls. 1, 2.

—— 1954. Stratigraphy and Micropalaeontology of the Marine Tertiary rocks between Adelaide and Aldinga, South Australia. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.*, Rep. No. **12** : 1–65, pls. 1–7.

—— 1955. The Cape Range structure Western Australia: pt. 2 Micropalaeontology. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.*, **21** : 49–82, pls. 7–10.

EAMES, F. E., BANNER, F. T., BLOW, W. H. & CLARK, W. J. 1962. *Fundamentals of Mid-Tertiary stratigraphical correlation.* London (Cambridge University Press).

DAVIES, A. M. 1927. Lower Miocene Foraminifera from Pemba Island. pp. 7–12. *In*: Stockley G. M. (see below). *Report. Palaeont. Zanzibar Protectorate.*

DIZER, A. 1962*a*. Les foraminifères de l'Eocène et l'Oligocène de Denizli. *Rev. Fac. Sci. Univ. Istanbul* (B) **27** : 39–47, pls. 1–7.

—— 1962*b*. Foraminifera of the Miocene of the Sivas Basin (Turkey). *Rev. Fac. Sci. Univ. Istanbul* (B) **27** : 49–85, pls. 1–9.

GORDON, W. A. 1961. Foraminifera from the 4CPR oil test well near Arecibo, Puerto Rico. *Publ. Puerto Rico Mining Comm.*, **1961** : 25–40.

GRIMSDALE, T. F. 1952. Cretaceous and Tertiary foraminifera from the Middle East. *Bull. Br. Mus. nat. Hist.* (Geol.) **1** : 221–248, pls. 20–25.

HANZAWA, S. 1957. Cenozoic foraminifera of Micronesia. *Mem. geol. Soc. Am.*, **66** : 1–163, pls. 1–38.

HOTTINGER, L. 1963. Quelques Foraminifères porcelanés oligocènes dans la série sédimentaire prebetique de Moratalla (Espagne méridionale). *Eclog. geol. Helv.*, **56** : 963–972, pls. 1–5.

HOUSE, M. R., DUNHAM, K. C. & WIGGLESWORTH, J. C. 1961. Geology and structure of the Maltese islands: 25–33. *In:* Bowden-Jones, Dewdney & Fisher. *Malta; Background for Development*, Newcastle.

JONES, T. R. & CHAPMAN, F. 1900. On the foraminifera of the orbitoidal limestones of Christmas Island: 226–264, pls. 20, 21. *In:* Andrews, C. W. *A monograph of Christmas Island (Indian Ocean).* Brit. Mus. (Nat. Hist.), London.

LOEBLICH, A. R. & TAPPAN, H. 1964. *Sarcodina chiefly " Thecamoebians " and Foraminiferida.* Treatise on Invertebrate Palaeontology, Pt.C, Protista 2. Geol. Soc. Amer. & University of Kansas Press.

LUDBROOK, N. H. 1961. Stratigraphy of the Murray Basin in South Australia *Bull. Geol. Surv. S. Aust.*, **36** : 1–96.

—— 1963. Correlation of the Tertiary rocks of South Australia. *Trans. Roy. Soc. S. Aust.*, **87** : 5–15.

—— 1965. Tertiary fossils from Christmas Island (Indian Ocean) *Jl. geol. Soc. Australia,* **12** : 285–294, pls. 21, 22.

MARIE, P. 1955. Quelques formes nouvelles de Polypiers et de Foraminifères de l'Oligocene et du Miocene du N.W. de la Grèce. II Foraminifères. *Bull. Soc. geol. Fr.* (6) **5** : 193–205, pls. 18–20.

PARR, W. J. 1942. New genera of foraminifera from the Tertiary of Victoria. *Min. geol. Jb.*, **2** : 361–363.

RAO, S. R. N. 1941. The Tertiary sequence near Surat and Broach (Western India) with descriptions of foraminifera of the genus *Pellatispira* from the Upper Eocene of this region. *Half yearly Jl., Mysore University* (n.s.B), **2** : 5–17, pls. 1, 2.

RENZ, O. 1936. Stratigraphische und mikropaläontologische Untersuchung der Scaglia (Obere Kreide–Tertiär) im zentralen Appenin. *Eclog. geol. Helv.*, **29** : 1–149, pls. 1–15.

SCHLUMBERGER, C. 1893. Note sur les genres *Trillina* et *Linderina*. *Bull. Soc. geol. Fr.* (3) **21** : 118–123, pl. 3.

SILVESTRI, A. 1920. Fossili rari o nuovi in Formazione del Paleogene. *Boll. Soc. geol.., Ital* **39** : 57–80, pl. 4.

—— 1929. Osservazioni so Fossili Nummulitici. *Riv. ital. Paleont.*, **35,** fasc. 1–11: 1–21, pls. 1–3.

—— 1937. Paleontologia delle Somalia. V. Fossili dell'Oligocene e del Miocene. 3. Foraminiferi dell'Oligocene e del Miocene della Somalia. *Palaeontogr. ital.*, **32**, supp. 2 : 45–264, pls. 4–22.

SMOUT, A. H. & EAMES, F. E. 1958. The genus *Archaias* (Foraminifera) and its stratigraphical distribution. *Palaeontology*, **1**: 207–225, pls. 39–41.

STEFANINI, G. 1921. Fossili Tertiari della Cirenaica. *Palaeontogr. ital.*, **37** : 101–143, pls. 16–28.

STOCKLEY, G. M. 1927. Stratigraphy of the Zanzibar Protectorate. 5–6 *Rep. Paleont. Zanzibar Protectorate.*

TISSOT, M. B. & NOESMOEN, A. 1958. Les Bassins de Noumea et de Bourail, (Nouvelle Caledonie). *Rev. Inst. Pet.* **13**: 739–760.

TODD, R. & POST, R. 1954. Smaller foraminifera from Bikini drill holes. *Prof. Pap. U.S. geol. Surv.*, **260-N** : 547–568, pls. 198–203.

TODD, R. & LOW, D. 1960. Smaller foraminifera from Eniwetok drill holes. *Prof. Pap. U.S. geol. Surv.*, **260-X** : 799–861, pls. 255–264.

VLERK, I. M. VAN DER & UMBGROVE, J. H. F. 1927. Tertiare Gidsforaminiferen van nederlandisch oost-indie. *Wet. Meded. Dienst. Mijnb. Ned.-Oost Indie*, **6** : 3–31.

WAYLAND, E. J. & DAVIES, A. M. The Miocene of Ceylon. *Quart. Jl. geol. Soc. Lond.*, **79** : 577–602, pls. 28–9.

PLATE 1

Austrotrillina asmariensis sp. nov.

All $\times 50$ approximately

FIG. 1. B form, P39430. Kirkuk Well 56. Henson colln.

FIG. 2. A form, P43667. Bajawan limestone, Kirkuk. Smout & Eames colln.

FIG. 3. A form, P39647. Kirkuk Well 56, Henson colln. (Figs. 2, 3 = *A. howchini sensu* Smout & Eames 1958).

FIG. 4. Off-centre, axial section, P47579. Sample J.T.P.4943, Kuh e Pataq, Luristan. Oligocene.

FIG. 5. Holotype, P47578. Sample J.T.P.4943, Kuh e Pataq, Luristan, Oligocene.

FIG. 6. Off-centre, transve rsesection, P47580. Sample J.T.P.4890 Kuh e Pataq, Middle Oligocene.

FIG. 7. A form, P47581. Kirkuk Well K93, core 2, 2655 ft. 3 in. Ex. I.P.C. colln.

FIG. 8. A form, P47582. Gach Saran Well 6, 4132–33 ft. Asmari limestone, Iran.

FIGS. 9, 10. A forms, P47583. Kirkuk Well K14, 2793–2808 ft. Ex. I.P.C. colln.

FIG. 11. A form, P47584. Kirkuk Well K93, core 2, 2655 ft. 3 in. Ex. I.P.C. colln.

FIG. 12. B form. P47585. Gach Saran Well 6, 4135–36 ft., Asmari limestone, Iran.

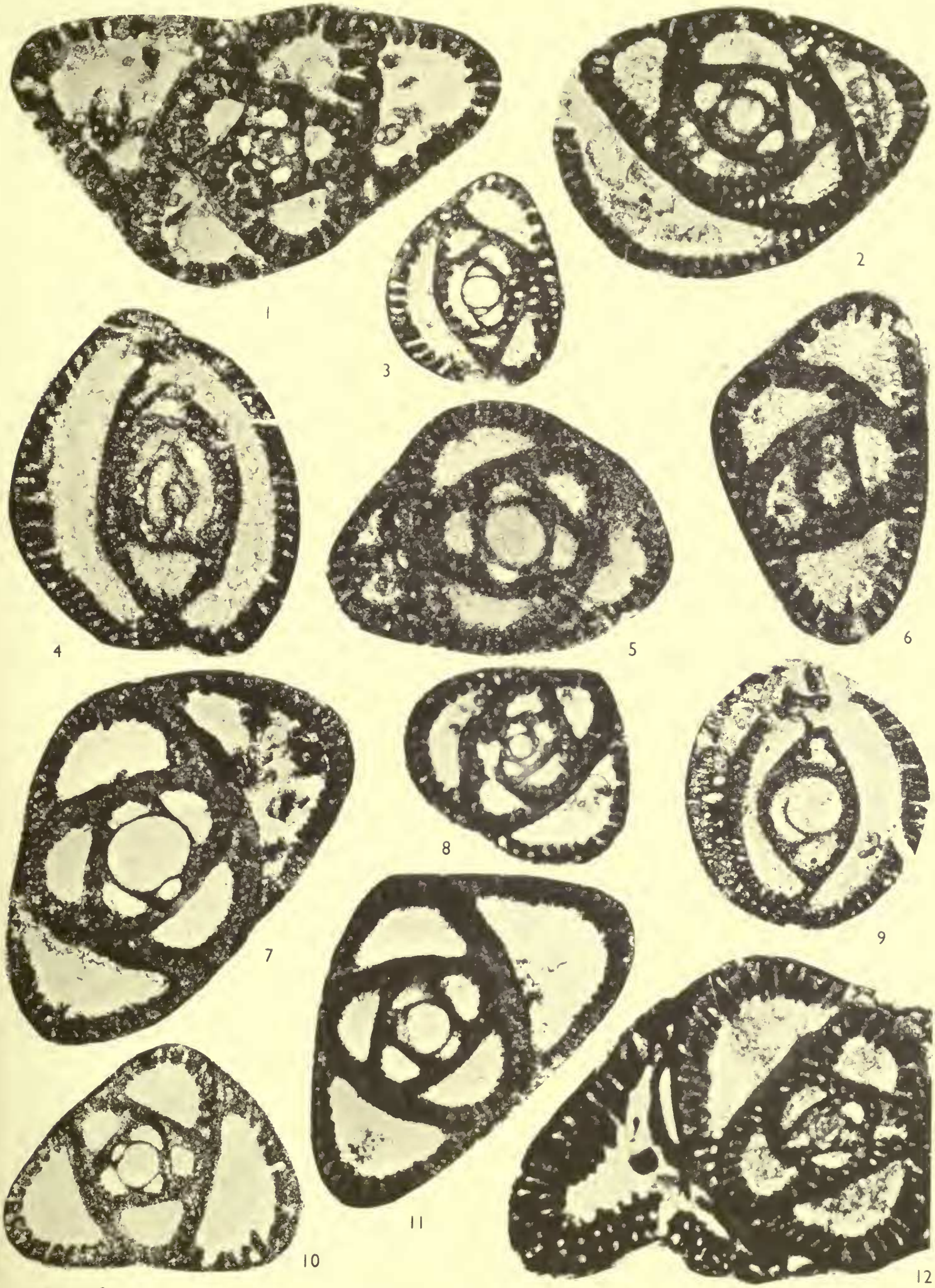

1
2
3
4
5
6
7
8
9
10
11
12

PLATE 2

Austrotrillina howchini (Schlumberger)

All from the Pata limestone- drill hole P.Q. 2, 273–75 ft., Chowilla Dam site, South Australia. Lower Miocene (Bairnsdalian). Ex. Geol. Surv. S. Australia collections.

FIGS. 1, 2. P47586. (1) External view of test × 35 ; (2) portion of wall more highly magnified showing finely pitted outer surface and sub-surface reticulation. See also Pl. 6, fig. 7.

FIG. 3. Transverse section of A form, × 48, P47587.

FIG. 4. Transverse section of a more inflated A form, × 50, P47588.

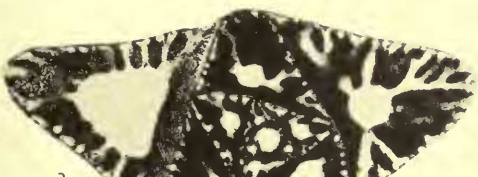
FIGS. 5, 7. Decorticated A form, P47590 (cf. Fig. 1). Most specimens of *Austrotrillina* are found in this condition: (5) × 35: (7) same specimen × 50.

FIG. 6. A form, P47589. Axial section of a specimen which closely resembled fig. 1 externally.

For B form see Plate 6.

1

2



3

6

4

5

7

PLATE 3

Fig. 1. ***Austrotrillina paucialveolata.*** Syntype ×48, P40681; Kirkuk Well No. 14, Oligocene. Probably a B form.

Fig. 2. ***A. paucialveolata.*** A form, ×50, P47591; Kirkuk Well 14, 2828–53 ft., Oligocene.

Fig. 3. ***A. paucialveolata.*** A form, ×50, P40344; Kirkuk Well 14, 2828–53 ft., Oligocene.

Fig. 4. A form, ×50, P40681 (syntype): Kirkuk Well 14.

Figs. 5, 6. ***A. paucialveolata.*** A form, Oligocene of Moratalla, Spain (= *A. howchini* of Hottinger 1963) (5) ×55; (6) ×50. Deposited in the Naturhistorisches Museum collections, Basle.

Fig. 7. ***A.*** cf. ***striata*** ×50. Lower Coralline limestone, Malta, Brt. Petrol. Co., Colln.

Fig. 8. ***A. striata,*** ×50. Wall partly destroyed by recrystallization. This specimen is indistinguishable from *A. paucialveolata* and is only determinable as *A. striata* from associated individuals. Tagpochau limestone, Saipan. U.S.G.S. colln., sample No. MSB 260.

Fig. 9. ***A. striata/howchini*** ×50. Bikini drill hole 2B 2038½–48 ft. This is one of the specimens figured by Cole (1954) as *A. howchini* and refigured in the *Treatise* (1964, fig. 362–8) under the same name. It is, in fact, intermediate between *A. howchini* and *A. striata.* U.S.N.M. Colln.


1
2
3
4
5
6
7
8
9

PLATE 4

Austrotrillina striata Todd & Post

All ×50 unless otherwise stated

FIGS. 1–3. A forms (P47592, P47593) from Eniwetok drill hole E-1, 1895–925 ft. Figs. 1, 2 are of the same individual. Fig. 2 shows the external appearance of the test when immersed in oil; decorticated specimens also look like this.

FIGS. 4, 7. A forms from Eniwetok drill hole E-1, 1925–55 ft. U.S.N.M. colln. (4) transverse section, (7) longitudinal section. Note that the alveolar structure is not visible in the early chambers.

FIGS. 5, 9, 11–13. All from Eniwetok drill hole E-1, 1925–55 ft. (5) P47594, A form; (9) surface view of typical specimen showing fine striae, P47597; (11) longitudinal section through A form; P47599; (12) wall of terminal chamber viewed from inside, ×56, P47600; (13) A form, terminal chamber broken off—note ' step ', P47601.

FIGS. 6, 10. A forms from Eniwetok drill hole E-1, 1996½–2007 ft., P47595 & 47598.

All ex. U.S.G.S. collection.

FIG. 8. A form (P47596) from Bikini drill hole 2B, 2049–2059½ ft. Topotype. Ex U.S.G.S. colln.

PLATE 4

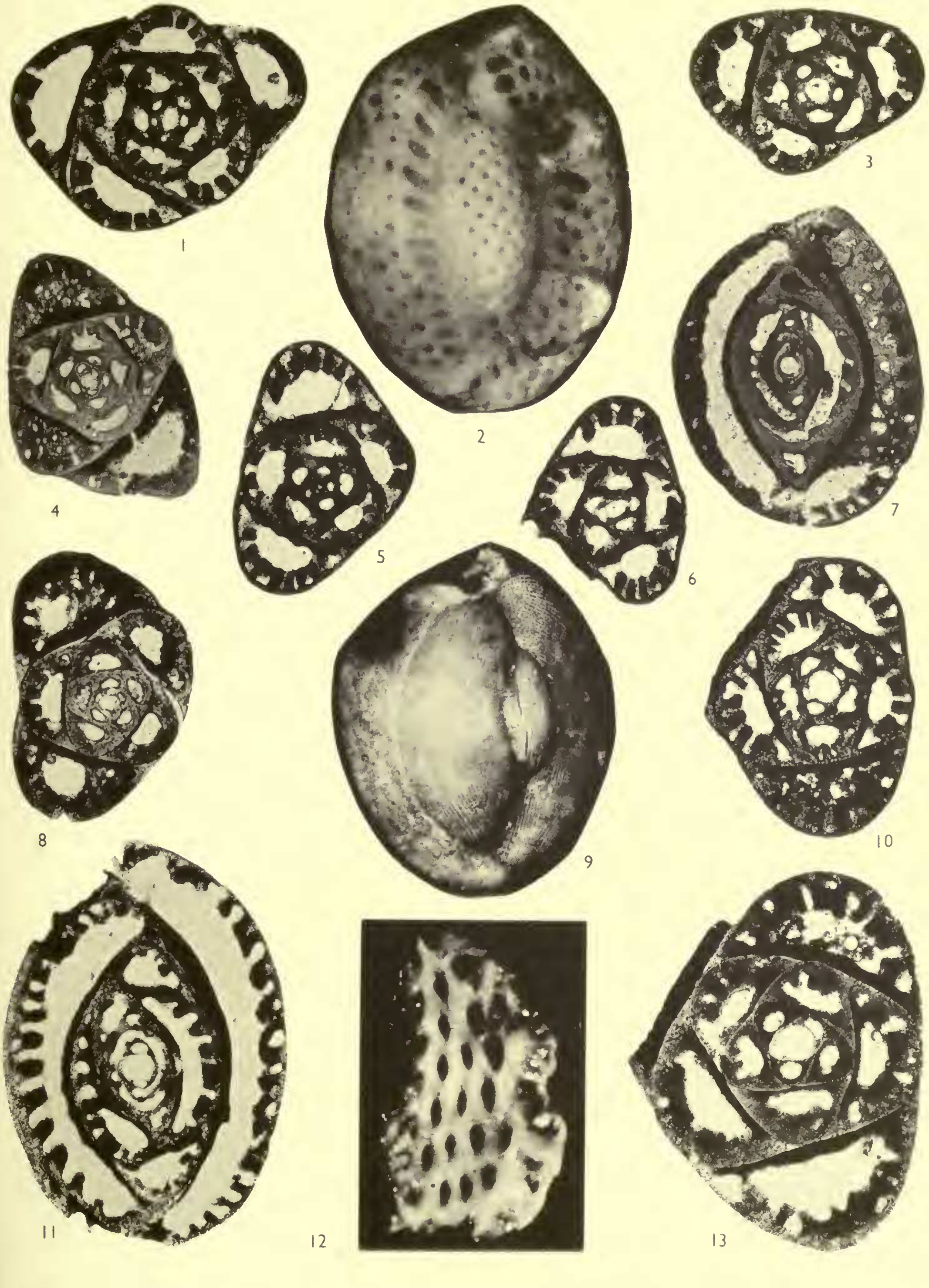


PLATE 5

The figures on this plate illustrate the difficulty in determining specimens from certain Indo-Pacific (Upper Te) limestones where transitional forms between *A. striata* and *A. howchini* occur, or where the range of variation of *A. striata* overlaps that of *A. asmariensis.*

FIG. 1. ***Austrotrillina*** sp. ×50, P46525. Intermediate between *A. striata* and *A. howchini.* Upper Te, Melinau limestone, Sarawak.

FIG. 2. ***A. striata*** ×52, P46526. Upper Te, Melinau limestone, Sarawak.

FIG. 3. ***A. striata*** ×50, P46522. Lower Te, Melinau limestone, Sarawak.

FIG. 4. ***A.*** cf. ***howchini*** ×50, P46524. Upper Te, Melinau limestone, Sarawak.

FIGS. 5, 11. ***A.*** cf. ***howchini*** ×50, P47602, P47606. Primitive forms from the Tagpochau limestone, Saipan. Sample No. MSB 413. U.S.G.S. colln.

FIGS. 6, 7. ***Austrotrillina*** sp. ×50. Tagpochau limestone, Saipan U.S.G.S. colln. Sample No. MSB 397, Lower Te. These specimens are not strictly determinable In some respects they resemble *A. asmariensis,* in others *A. striata/howchini* (6) P47603; (7) P47604.

FIG. 8. ***Austrotrillina*** sp. ×50. Tagpochau limestone, Saipan, Sample No. MSB 403, U.S.G.S. colln. Intermediate between *A. striata* and *A. howchini.*

FIG. 9. ***A.*** cf. ***striata*** Todd & Post, B form, ×50, P47605. Tagpochau limestone, Saipan. Ex Sample No. B397, U.S.G.S. colln.

FIG. 10. ***A.*** cf. ***howchini*** ×50. Part of wall of a specimen from the Tagpochau limestone, Saipan. Sample No. MSB 388, U.S.G.S. colln.

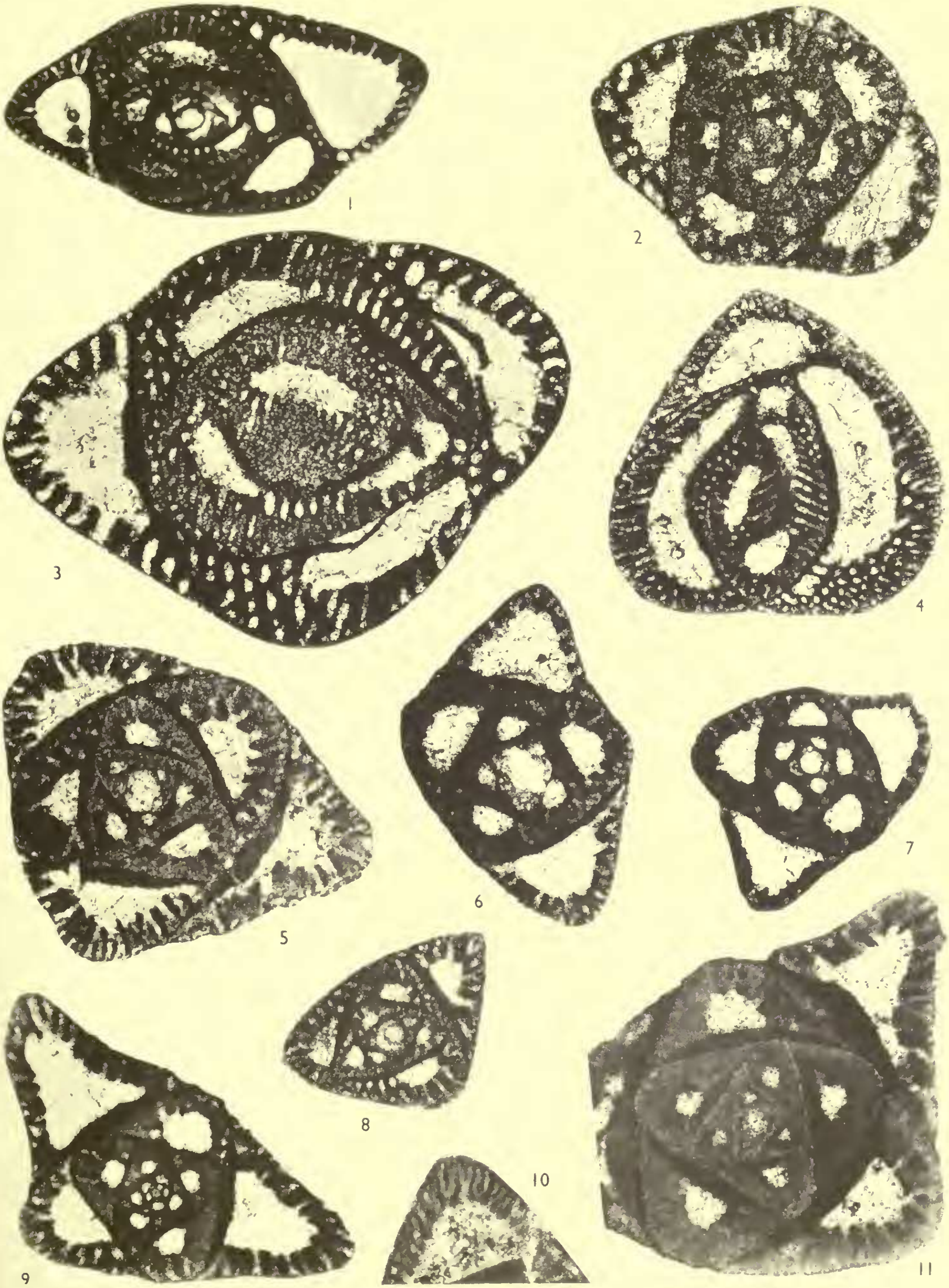

1
2
3
4
5
6
7
8
9
10
11

PLATE 6

FIG. 1. ***Austrotrillina howchini***, A form $\times 50$. Lower Chake beds, south end of Funzi Island, Pemba Island, Tanzania. P22848.

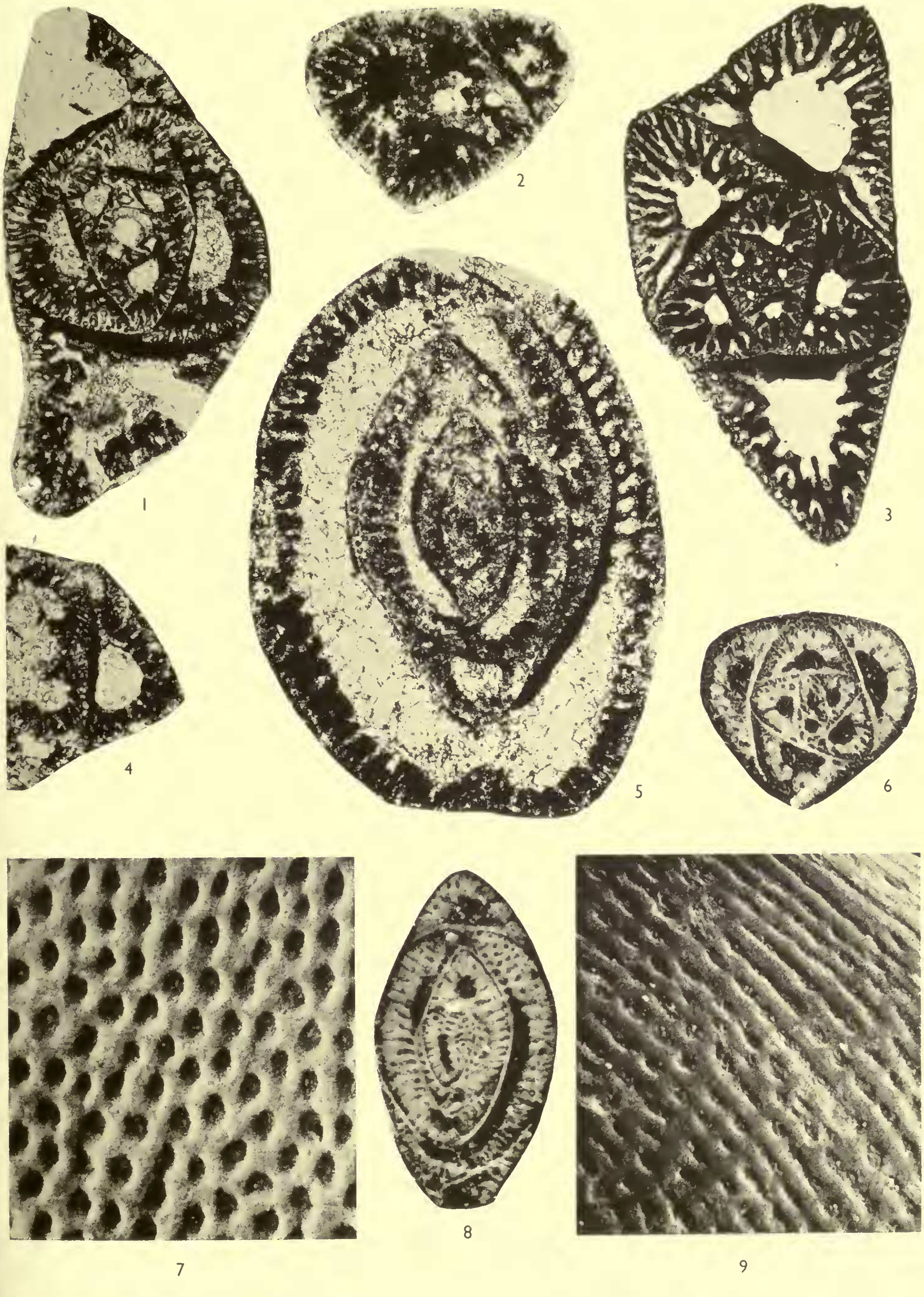
FIGS. 2, 4, 5. ***A. howchini.*** All $\times 50$. P47607 (ex. P29878). All from the Lower Miocene of the Malabar coast, Cochin, Travancore, India. Associated with *Taberina malabarica* (Carter) for which this is the type locality: Carter collection.

FIG. 3. ***A. howchini.*** B form, $\times 40$, P47608. Pata limestone, Chowilla Dam site, South Australia. Lower Miocene (Lower Tf).

FIGS. 6, 8. ***A. brunni.*** Re-illustration of two of Marie's types: $\times 35$ and $\times 50$ approx.

FIG. 7. ***A. howchini.*** Stereoscan electron microscope photograph showing surface pits. The subsurface reticulation is no longer visible as the specimen is coated with a fine gold film. Same individual as Pl. 2, figs. 1, 2. $\times 750$, KV 20.

FIG. 9. ***A. striata.*** Stereoscan electron microscope photograph showing surface striae and pits. Bikini Well 2b, 2091–2102 feet. P47609 $\times 750$, KV20. Note that the pits are smaller than in *A. howchini*.


1
2
3
4
5
6
7
8
9